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EXECUTIVE SUMMARY

Risering software written for PMRL by Dr. R.W. Smith and Dr. M.R. Viner of the Department of Metallurgical Engineering at Queen's University has been tested out with two commercial foundries. Both pointed out two desirable extensions to the programme.

First, the programme should treat the case in which a ring-shaped riser is used on a hollow-cylinder casting. Second, the programme should analyse casting designs in which different regions are fed by both open and blind risers.

This report summarizes the changes to the programme necessary to accommodate those extensions, the addition of two elementary shapes useful in describing the size and shape of casting sections, and the extension of the ring riser design to tapered rectangular risers ("wedge" risers).

Le software de calcul de masselotte, écrit pour le PMRL par les Dr. R.W. Smith et M.R. Viner du département de génie mécanique à l'université de Queen's, a été essayé par deux fonderies commerciales. Leur conclusion commune a été un souhait d'élargissement du programme.

Dans un premier temps, le programme devrait permettre de traiter le cas où une masselotte en forme d'anneau est utilisée sur un cylindre de coulée creux. En second lieu, ce programme devrait également autoriser l'analyse des schémas de coulée dans lesquels différentes régions seraient alimentées par des retassures aussi bien ouvertes que fermées.

Ce rapport résume les modifications à apporter au programme de manière à satisfaire les élargissements, l'addition de deux formes élémentaires nécessaires à la description de la taille et de la forme des sections de coulée, ainsi que l'adaptation du schéma de masselotte en forme d'anneau à celui de masselottes rectangulaires effilées (masselottes à "coins").

Alterations to Software to Accommodate Tapered Risers
and Interaction between Open Risers and Blind Risers

A. Tapered Risers

Many foundries use a tapered ring riser to feed a section which includes a hollow cylinder of appropriate size. Some also use a wedge riser to feed a section which includes a plate or a bar, if geometrical restrictions require it.

In both cases, the dimensions of the bottom of the riser are fixed by the size of the underlying casting section, and the program must calculate either the height or the top width of the riser for successful feeding of the riser section.

Because of the extra "types" of riser now available to the user of the programme, we have split the Riser Type Menu into two parts. The first part determines the basic geometrical shape, and consists of:

1. Cylindrical Sleeved Riser
2. Cylindrical Sand Riser
3. Ring Riser
4. Wedge Riser

Choices 3 and 4 assume no exothermic or insulating sleeves are being used.

The second part of the Riser Type Menu determines the riser topping to be used:

1. Hot Topping
2. Insulated Top
3. Blind Top
4. Open Top

The sand top is never used with ring or wedge risers. Open top risers are seldom used, as the top can freeze off early, causing feeding problems.

Tapered risers have a fundamentally different geometry from cylindrical risers. Hence a new algorithm was developed by K. Davis to calculate the shrink profile in tapered risers. The geometric cross-section of a tapered ring riser is shown in Figure A1. The inner diameter of the base of the ring is taken to be DD, and is assumed to be large in comparison with AA.

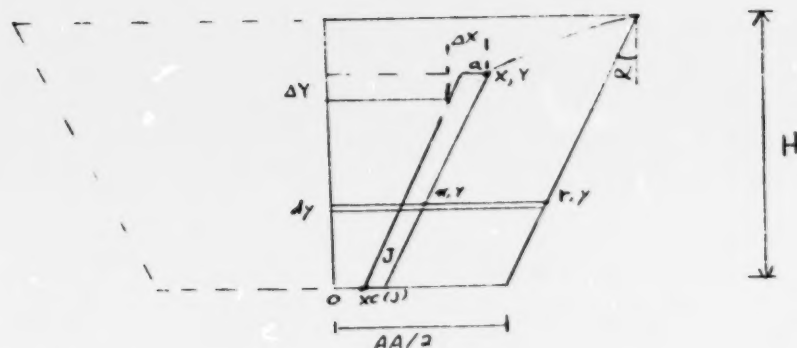


Fig. A1. Cross-sectional geometry of a tapered riser.

If we assume that each horizontal slice dy of the riser loses heat only from the sides, and that the rate of solidification is inversely proportional to the square root of time, then

$$\frac{\text{volume solidified}}{\text{initial volume}} = \frac{r-x}{r} = \frac{t^{1/2}}{r \cos \alpha \sqrt{K_m}}$$

From this equation, we see that at any given time, x is independent of y , and the solid-liquid interface is planar and parallel to the outer surfaces.

When a layer Δx solidifies, the volume of metal solidified is:

$$\Delta V_{SR} = Y.a. 2\pi (DD + AA)$$

and the reduction of liquid volume in the riser is:

$$\Delta V_L = X.\Delta Y. 2\pi (DD + AA)$$

These equations are related through the solidification shrinkage factor S :

$$S = \Delta V_L / [\Delta V_{SR} + \Sigma \Delta V_g (N)]$$

where $\Sigma \Delta V_g (N)$ is the total shrink in the time interval considered for all of the subsections fed by the riser. There are NN sub-sections, numbered zero through $NN-1$.

For the solidification zone J, let

$$C(J) = \sum_{0}^{NN-1} V(N)/M(N)$$

where $V(N)$ and $M(N)$ are the volume and modulus of those sub-sections which are not yet solidified in zone J.

Then if $P = MR/VR$, the shrinkage factor S becomes

$$S = \frac{X \Delta Y}{Y (\Delta X - \Delta Y \tan \alpha) (1 + P.C(J))}$$

from which we can write the differential equation:

$$\frac{dY}{dX} = \frac{S.Y. (1 + P.C(J))}{X + S.Y. \tan \alpha (1 + P.C(J))}$$

Given the boundary condition that $x = X(J-1)$ when $y = Y(J-1)$, the solution to the equation is:

$$\frac{Y}{Y(J-1)} = \left[\frac{\begin{matrix} X \\ - .N(J) + \tan \alpha \\ Y \end{matrix}}{\begin{matrix} X(J-1) \\ \frac{X(J-1)}{Y(J-1)} .N(J) + \tan \alpha \end{matrix}} \right]^{\frac{1}{N(J)}}$$

where

$$N(J) = \frac{1 - S(1 + P.C(J))}{S (1 + P.C(J))}$$

By re-arranging the solution, we cannot express Y in terms of X , but we can find X explicitly in terms of Y :

$$X = \left[\frac{X(J-1)}{Y(J-1)} + \frac{\tan \alpha}{N(J)} \right] \cdot Y \cdot \left[\frac{Y}{Y(J-1)} \right]^{N(J)} - \frac{Y \cdot \tan \alpha}{N(J)}$$

In the final solidification zone, the casting takes no part in the solidification shrinkage. Hence we get:

$$Y = Y(JJ) + \frac{S}{1-S} \cdot \frac{X - X(J)}{\tan \alpha}$$

where JJ is the zone for which $XC(J)=0$.

For a wedge riser with a length DD large in comparison with the width AA, equations A2 and A3 become:

$$\Delta V_{SR} = Y.a.2DD$$

$$\Delta V_L = X.\Delta Y.2DD$$

but equations A1 and A7, and the solution of A7 remain the same.

B. Shape Menus

When describing the shape and size of a casting section, the foundryman occasionally needs to specify a triangular prism or a cone. Accordingly, these two shapes were added to the 10 fundamental shapes already available in the Casting Shape/Size option.

For the sake of clarity, the shape groupings were renamed "Linear" and "Curved" instead of "Rectangular" and "Annular".

C. Blind Riser/Top Riser Interaction

Some castings are most conveniently fed by a blind bottom riser and one or more top risers. For those castings, the top riser will actually feed the bottom risered section until the "choke" point between the risered sections freezes off. Hence, some allowance must be made for the size of the top riser whose section is connected to a blind bottom-risered section.

In order to allow for this interaction, we have added the variable "BLIND" to the program as a flag to keep track of the progress in calculating the two interacting risers. The values assumed are:

- BLIND = 0: Initial value
- 1: No interaction between bottom & top risers
 - 2: Interaction will occur; no calculations yet
 - 3: The blind riser has been designed
 - 4: Section/riser data has been stored for the blind riser
 - 5: The connected top riser has been designed
 - 6: Section/riser data has been stored for the connected top riser.

Before entering the Casting Shape/Size option for the first time, the user is asked whether there will be an interaction of this type. If the answer is NO, then the program sets BLIND=1 and proceeds. If the answer is YES, then the program sets BLIND=2 and instructs the user to first design the blind bottom riser, save the section/riser data to disk, and then design the top riser for the connected section. The sub-section connecting these two risered sections (the "choke" point) must be associated with the bottom riser.

Thereafter, the program tries to guide the user through the proper design path by testing the value of BLIND at various times. The program will store the blind riser as riser number zero, and will treat the blind riser and its sub-sections as if they were extra sub-sections attached to the top riser. When the choke point freezes off, the Riser Size/Neck part of the program will ignore any bottom risered sub-sections that are still molten.

When the risered sections are summed in the Gating System option, riser number zero is ignored, since all of its components are included in the sub-sections of the connected top riser.